

SPECIFICATION

TITLE: EMERGENCY VEHICLE TRAFFIC SIGNAL PREEMPTION SYSTEM

Priority of United States Provisional Application Serial No. 60/403,916 filed August 15, 2002 is hereby claimed.

BACKGROUND OF THE INVENTION

## 1. Field of the Invention

This invention relates to systems for controlling vehicle traffic signals to allow safe passage of emergency vehicles and more particularly relates to a system for autonomously preempting traffic signals at an intersection that includes a transponder, a real-time intersection monitor, and an audio alarm or warning system.

## 2. Background Information

Present systems used to preempt traffic signals and clear intersections for emergency vehicles responding to a life-saving event rely on: sound activation, optical activation, direct microwave activation, and a combination of all the above. All of these systems have severe operational limitations affected by weather, line of sight, and critical range. These systems have further drawbacks requiring them to be activated by the emergency vehicle operator. None of these known systems provide real-time monitoring of intersection phases which has the added affect that an operator does not get the feedback desired and soon stops using the system.

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By: 

David C. Reilly, Reg. No. 26,102

1        Also emergency vehicles currently rely on vehicle horn,  
2 sirens, and flashing lights to prevent accidental collisions  
3 with pedestrians or other vehicles at intersections. An  
4 intersection-based system that would be activated remotely (and  
5 autonomously) by an approaching emergency vehicle is needed.  
6 Such a system overcomes some of these drawbacks of available  
7 systems by including an audible warning, most likely instructing  
8 nearby pedestrians to clear the intersection.

9        Visual displays at intersections may provide warnings to  
10 motorists and pedestrians yet they may fail to get the attention  
11 of pedestrian standing near an intersection. A visual sign may  
12 be barely visible at significant viewing angles and pedestrians  
13 will likely not be looking in the direction of any sign. For  
14 this reason, audible alerts in addition to visual may be the  
15 most effective (and rapid) warning system of the approach of  
16 emergency vehicles.

17        There is also the difficulty that pedestrians may often be  
18 in harms way if they fail to hear an approaching emergency  
19 vehicle. Although vehicle sirens are especially loud, many  
20 circumstances can lead to dangerous situations and potential  
21 injury. For instance, an especially long crosswalk may take up  
22 to 20 seconds to cross. In that time, an emergency vehicle may  
23 be heard, perhaps stranding the pedestrian in the middle of a  
24 crosswalk. Likewise, in extremely busy metropolitan  
25 intersections, ambient noise in the building occlusions may

1 prevent warning of the emergency vehicle until just seconds  
2 before the vehicle arrived at an intersection. Previous  
3 experience with visual warning systems show that pedestrians are  
4 often unable to see the visual warning signs sufficiently during  
5 demonstrations.

6 It is one object of the present invention to provide an  
7 emergency vehicle traffic signal preemption system that is fully  
8 autonomous and not dependent on the intersection being in visual  
9 range.

10 Still another object of the present invention is to provide  
11 an emergency vehicle traffic signal preemption system that  
12 provides conflict detection and alerts other emergency vehicles  
13 in the area.

14 Still another object of the present invention is to provide  
15 an emergency vehicle traffic signal preemption system that  
16 includes a real-time monitor of intersection phase.

17 Yet another object of the present invention is to provide  
18 an emergency vehicle preemption system having an emergency  
19 vehicle transponder including an on-board diagnostic interface,  
20 a navigation interface, and a communications monitor and control  
21 interface.

22 Still another object of the present invention is to provide  
23 an improved emergency vehicle traffic signal preemption system  
24 including a real-time intersection status monitor.

25 Still another object of the present invention is to provide

1 an emergency vehicle traffic signal preemption system that  
2 includes a pedestrian audio warning signal to supplement the  
3 visual display and the audio signals from emergency vehicles.

4 BRIEF DESCRIPTION OF THE INVENTION

5 The purpose of the present invention is to provide an  
6 improved emergency vehicle traffic signal preemption system  
7 including autonomous operation, real-time phase monitoring and  
8 audio signals to alert pedestrians of the approach of emergency  
9 vehicles.

10 The system is fully autonomous and is not affected by  
11 range, weather, or line of sight. It provides real-time  
12 monitoring of the intersection phases to provide the visual  
13 display to alert motorist of oncoming emergency vehicle and the  
14 direction it is coming from. This system is an improvement for  
15 use with the system disclosed and described in U.S. Patent No.  
16 4,704,610 of Smith et al issued November 3, 1987 and  
17 incorporated herein by reference. The system also provides an  
18 added feature of conflict indication to the emergency vehicle  
19 operator, indicating that another emergency vehicle is  
20 responding and is approaching the same intersection, indicating  
21 which vehicle has the preemption and right of way.

22 This system is unique in that it is fully autonomous and  
23 not dependent on the intersection being in visual range. It  
24 provides conflict detection and alerts other emergency vehicle  
25 operators in the area, has the ability to interrupt pedestrian

1 access, stops preemption when an emergency vehicle stops, and  
2 provides interface to and control of the system disclosed and  
3 described in the above-identified patent.

4 The improved emergency vehicle traffic signal preemption  
5 system consists of three major subsystems. An intersection  
6 monitor and control, an emergency vehicle transponder and its  
7 interfaces, and a wide area communications network and its  
8 associated proprietary control program software. The emergency  
9 vehicle intersection preemption design connects intersections  
10 and vehicles over a two-way wide area wireless communications  
11 network. This network is synchronized via Global Positioning  
12 System (GPS) timing signals.

13 When an emergency vehicle operator receives an emergency  
14 response request, the vehicle is placed in a Code 3 mode with  
15 lights and sirens operating, at the same moment the vehicle  
16 preemption transponder reads the vehicle on-board diagnostics  
17 (OBD) data and determines speed and acceleration, and gathers  
18 navigation data from one of several navigation systems. This  
19 data is collected by an on-board microprocessor that processes  
20 this information, determines heading and position, which is then  
21 formatted, the vehicle identification (ID) added, and the data  
22 is then transmitted to various intersections within the design  
23 area of coverage.

24 The intersection processor receives the data, identifies  
25 the vehicle time of arrival, compares it with other vehicles

1 approaching an intersection, and determines which vehicle will  
2 arrive first, and sends notification to all approaching  
3 emergency vehicles that there is a conflict and identifies for  
4 an operator which vehicle has the right of way.

5 Simultaneously the processor collects real-time  
6 intersection base monitor output and calculates when preemption  
7 should start, and when to inhibit pedestrian crossing access.  
8 When preemption starts, a visual display is sent coded commands  
9 via a wireless connection to light the proper icons for each  
10 direction showing emergency vehicle approach, direction, and  
11 lighting emergency vehicle approach message. All this takes  
12 place in real time and in a manner appropriate to insure an  
13 intersection is preempted early enough to assure a safe and  
14 clear path for an emergency vehicle.

15 The system disclosed herein provides a number of  
16 improvements of the above-identified patent. It is an  
17 autonomous system that does not need involvement of emergency  
18 vehicle operator. It also includes expanded system capabilities  
19 using emergency vehicle on-board diagnostics (OBD), monitoring  
20 multiple emergency vehicles approaching the same intersection  
21 using Global Positioning System (GPS), and speed and heading  
22 information for multiple emergency vehicles to determine the  
23 right of way. An intersection status is transmitted to  
24 emergency vehicle dashboards indicating when the intersection is  
25 safe to traverse. A dashboard display indicates to the vehicle

1 operator the status of an intersection. The system also  
2 includes a wide area wireless RF communication links between  
3 emergency vehicles and intersections. This system is reliable  
4 and unaffected by weather, rain, or lack of line of sight.

5 The system includes real-time monitoring of all  
6 intersection traffic lights by a fail-safe, isolated, high  
7 impedance tap and subsequent digital circuit processing to  
8 provide intersection status to each emergency vehicle.  
9 Simultaneously, pedestrian audio alerts are activated when  
10 emergency vehicles are approaching an intersection. These are  
11 important because often visual signs at an intersection may not  
12 be clearly visible to a pedestrian. Beepers, bells, sirens, or  
13 even spoken instructions at high volume can be used.

14 Several types of emergency vehicle location and navigation  
15 information retrieval are possible. Among these are Global  
16 Positioning Systems (GPS), dead reckoning, beacon triangulation,  
17 tags, traffic loop, RDIF, etc. Each vehicle has an  
18 identification (ID) that allows transmission to the appropriate  
19 vehicle that it has the right-of-way to a preempted  
20 intersection.

21 The improvements to the existing system in the above-  
22 identified patent are to enhance the performance but the purpose  
23 of the system remains the same. That is, to alert and stop  
24 vehicles and pedestrians from using an intersection to allow an  
25 emergency vehicle to pass safely. Some prior warning is

1 necessary to allow clearing the intersection. The previous  
2 implementation uses a one-way infrared link to transmit approach  
3 and departure information of emergency vehicle to the  
4 intersection which is equipped with four emergency vehicle  
5 status display panels mounted next to the usual traffic lights  
6 at each intersection.

7 The system transmits a signal causing all traffic lights at  
8 an intersection to switch to "red" thus stopping all traffic in  
9 all directions. In addition, the display panels flash a  
10 relatively large "emergency vehicle" therein with a graphic  
11 display indicating the lane and direction of traffic taken by an  
12 emergency vehicle. The range of the infrared transmitter can be  
13 as much as 1,000 feet allowing sufficient time to clear the  
14 intersection. The new improved system utilizes a wide area  
15 wireless RF two-way communication link between emergency  
16 vehicles and intersections. This method is more reliable and  
17 not affected by weather, lack of line of sight, range limitation  
18 or obstructions.

19 Another advantage of the two-way wireless RF communications  
20 link between the intersections and emergency vehicles is the  
21 ability to display much more useful data in the vehicles helping  
22 the vehicle operator maneuver his vehicle most efficiently and  
23 safely. Intersection status shows when an intersection has been  
24 preempted allowing safe passage. If more than one emergency  
25 vehicle approaches an intersection, the system determines which



1 vehicle should have the right of way depending on location  
2 information (GPS, traffic loop, beacon, etc.), direction and  
3 speed sent to the intersection control. A proprietary control  
4 program determines the right of way and sends the result to  
5 emergency vehicles. The data package transmitted over  
6 transceivers are tagged with the vehicle ID to insure proper  
7 utilization.

8 Another improvement to the system is an audio warning  
9 system intended to alert pedestrians that an intersection has  
10 been preempted and must be kept clear. One desirable  
11 implementation would utilize loudspeakers mounted near the four  
12 corners of the intersection where pedestrians normally gather to  
13 cross. A spoken message such as "Warning! Emergency Vehicle  
14 Approaching. Do Not Walk." may be most preferred but any  
15 audible signal such as a wailing sound, a siren, or any other  
16 familiar emergency sound may be utilized. The activation signal  
17 is issued by yet another feature of the improved implementation  
18 which is the real-time monitoring of all traffic lights at the  
19 intersection with fail-safe, high impedance taps and subsequent  
20 digital processing to generate a preemptive status signal that  
21 is then transmitted to the emergency vehicles. This feature  
22 assures that the preemption command has been executed.

23 Another goal of the improved system is creation of an  
24 autonomous system that is activated by reception of a Code 3  
25 status or alarm. The operator of the emergency vehicle can

1 concentrate on his primary duty which is to arrive at the sight  
2 of the emergency safely in the shortest time possible without  
3 worrying about the activation of the system. A Code 3 signal  
4 starts the process of communication between an intersection that  
5 is being approached and the emergency vehicle and the system  
6 performs the functions described above.

7 The information available from the emergency vehicle and  
8 intersection controllers may be transmitted to a central  
9 location such as a dispatch center or traffic control center to  
10 display the status of multiplicity of intersections and  
11 emergency vehicles. Such information being displayed on a  
12 status board can be invaluable in managing emergency situations  
13 in a more sufficient manner because it makes available  
14 information on a real-time basis for the officials in charge.

15 The above and other objects, advantages, and novel features  
16 of the invention will be more fully understood from the  
17 following detailed description and the accompanying drawings, in  
18 which:

#### 19 BRIEF DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a block diagram of intersection functions for  
21 an emergency vehicle signal preemption system.

22 Figure 2 is a block diagram of the functions in an  
23 emergency vehicle for the emergency vehicle signal preemption  
24 system.

25 Figure 3 is an example of a schematic block diagram of a

1 transponder use in emergency vehicles.

2 Figure 4 is an example of a schematic diagram of on-board  
3 diagnostic electronics for the emergency vehicle signal  
4 preemption system.

#### 5 DETAILED DESCRIPTION OF THE INVENTION

6 The details of the emergency vehicle traffic signal  
7 preemption system are illustrated in the block diagrams of  
8 Figures 1 and 2. Figure 1 illustrates the functional details of  
9 the system at each intersection while Figure 2 illustrates the  
10 functions of the system installed in an emergency vehicle.

11 Traffic light control system 100 at an intersection  
12 includes traffic light controller 20 that generates the  
13 appropriate sequence of on-time and off-time for the various  
14 traffic lights that controls vehicular and pedestrian traffic at  
15 an intersection. Traffic light controller 20 also has the  
16 capability to be forced by external signals into a mode that  
17 activates all "red" lights simultaneously to close the  
18 intersection allowing safe passage for emergency vehicles.  
19 Controller 20 is preferably a microprocessing circuit driving  
20 isolated lamp drivers but discrete designs are also feasible.  
21 Some intersections may be more complicated, controlling turn  
22 lanes with arrow lights, but the basic principles remain the  
23 same.

24 An example of an intersection being controlled by the  
25 system and functions disclosed and describe herein is shown in

1 Figure 1 of U.S. Patent No. 4,704,610 referred to hereinabove  
2 and incorporated herein by reference. This figure shows the  
3 signage and approach of emergency vehicles being controlled.  
4 The only feature missing is the pedestrian control signs at each  
5 corner which are an added feature of the invention disclosed and  
6 described herein.

7 Traffic light controller 20 generates signals to control  
8 pedestrian lights 22a, 22b, 22c, and 22d and also controls the  
9 operation of traffic lights 24a, 24b, 24c, and 24d. An  
10 intersection having traffic lights can be connected to a system  
11 using the emergency vehicle preemption system by addition of the  
12 functions described hereinafter without the need to rebuild an  
13 existing installation.

14 The heart of the additional equipment is the communications  
15 controller 10, a microprocessor (e.g., a Zworld LP 3100 CPU)  
16 operated by proprietary control program software 35. Controller  
17 10 receives information from emergency vehicles that approach an  
18 intersection via wireless RF transceiver 40 and antenna 41.  
19 This information contains data about the position and heading of  
20 the emergency vehicle and that it is in a Code 3 alarm mode 36  
21 thus requesting preemption of the intersection.

22 Communications controller 10 sends a command to controller  
23 20 of the traffic light control system 100 forcing all "red"  
24 lights to come on stopping all traffic through the intersection.  
25 That means traffic lights 24a through 24d are all changed to

1 "red" while pedestrian lights 22a through 22d are changed to  
2 stop pedestrian traffic.

3 Real-time status monitor 42 is unique because it verifies  
4 that all "red" lights are activated and sends a "intersection  
5 preempted" signal to communications controller 10. That is,  
6 real-time status monitor receives (i.e., "reads") the output  
7 from traffic light controller 20 and pedestrian lights 22a  
8 through 22d and traffic lights 24a through 24d and transmits  
9 that information to communications controller 10.

10 Communications controller 10 in turn relays that information to  
11 emergency vehicles via wireless RF transceiver 40 and antenna  
12 41. Communications controller 10 now sends signals to emergency  
13 display panels 45a, 45b, 45c, and 45d to light and flash large  
14 emergency signs with the proper icons at each corner of an  
15 intersection showing the position of any approaching emergency  
16 vehicle relative to the traffic lanes of the intersection as  
17 shown and described in the above-identified U.S. patent  
18 incorporated herein.

19 The display panels 45a-45d and proper icons used at each  
20 corner of an intersection are shown in Figure 2 of the U.S.  
21 patent referenced hereinabove. The signage is also illustrated  
22 in U.S. Design Patent No. 305,673, issued January 23, 1990, also  
23 incorporated herein by reference.

24 Another improvement to the system is the provision of an  
25 audio warning to pedestrians. This is preferred because

1 pedestrians may often be put in harms way if they fail to hear  
2 an approaching emergency vehicle. Although vehicle sirens are  
3 especially loud, many circumstances can lead to potential  
4 injury. For example, a long crosswalk may leave a pedestrian  
5 stranded when an emergency vehicle is approaching or in busy  
6 metropolitan areas, ambient noise in building occlusions may  
7 prevent a pedestrian from hearing the approach of an emergency  
8 vehicle early enough. Further, experience with visual warning  
9 systems indicates that pedestrians are often unable to see the  
10 visual warning signs they may not be at the correct viewing  
11 angle. Thus simultaneously with controlling the lights and  
12 pedestrian flashing signals, controller 10 generates an audio  
13 message to be delivered from audio warning device 50 to speakers  
14 51a through 51d. Also, real-time status monitor provides  
15 information about the intersection to communications controller  
16 which is then transmitted via RF master transceiver 60 and  
17 antenna 61 to a central monitoring system such as a dispatcher's  
18 office.

19 The details of the software in the control program for  
20 implementing the functions of the system are not necessary  
21 because the functions controlled are described in great detail.  
22 Therefore many software solutions to implement the functions  
23 will be apparent to those skilled in the art.

24 Emergency vehicle functions for the preemption system are  
25 illustrated in the schematic block diagram of Figure 2. A

1 transponder is installed in each emergency vehicle and provides  
2 the functions that facilitates communication with preemptable  
3 intersections, and other emergency vehicles also central  
4 monitoring stations such as a dispatching center. Inputs and  
5 outputs to and from the emergency vehicle system are handled by  
6 communications controller 30 under the direction of proprietary  
7 control program software 15. Vehicle parameters are determined  
8 from several inputs provided to communications controller 30.

9 Vehicle position is available from GPS receiver 38 via  
10 antenna 39. Several positioning inputs are available from ports  
11 in navigation input device 34. Optional alternative inputs from  
12 ports and navigation input device 34 are tag, beacon, loop, etc.  
13 Vehicle information such as speed and acceleration are provided  
14 by on-board diagnostic (OBD) board 32 that generates the proper  
15 digital signals which are input to communications controller 30.

16 The emergency vehicle transponder system communicates with  
17 intersections via wireless RF transceiver 44 and antenna 45. It  
18 receives "intersection preempted" verification and displays the  
19 information on-board by activating one or more LEDs 56, 57, or  
20 58. If it receives a signal for safe passage through an  
21 intersection, "green" LED 56 is illuminated. If another  
22 emergency vehicle has the right of way at an intersection,  
23 "yellow" LED 57 is illuminated. With "yellow" LED 57  
24 illuminated, the emergency vehicle is notified that another  
25 emergency vehicle is approaching and has the right of way.

1 Illumination of "red" LED 58 indicates that there is no  
2 preemption at the intersection. LEDs 56 through 58 are driven  
3 by "intersection preempted" logic circuit 55.

4 Emergency vehicle status is available in real time via  
5 master RF transceiver 64 and antenna 65 to a central monitoring  
6 station. Thus the position of any vehicle as well as the status  
7 at an intersection is always available at some centrally located  
8 dispatch station.

9 As indicated previously, the software in control program 15  
10 to implement the functions of the transponder described above  
11 has many possible solutions. Thus the software provided to  
12 control the operation of communications controller 30 can be  
13 designed and implemented by anyone skilled in the art given the  
14 detailed explanation of the system and functions described  
15 hereinabove.

16 Figure 3 is a schematic block diagram of the transponder  
17 system mounted in each vehicle. The transponder box in the  
18 vehicle receives power from car battery 70 input to a DC to DC  
19 converter 72 activated by master power switch 74. The  
20 transponder box has a GPS receiver such as that produced and  
21 manufactured by Garmin International Incorporated. The  
22 transceiver can be a radio transceiver produced and manufactured  
23 by Freewave Technologies of Boulder, Colorado.

24 Figure 4 is a schematic diagram of the on-board diagnostic  
25 circuit for the in-vehicle electronics and transponder. The on-



1 board diagnostic circuit handles such information as speed,  
2 acceleration, heading, etc. and generates the proper digital  
3 signal delivered to communications controller 30.

4 Thus there has been disclosed improvements to an emergency  
5 vehicle traffic signal preemption system. Improvements include  
6 providing an autonomous system that is not dependent on  
7 intersection being in visual range. The system provides  
8 conflict detection and alerts emergency vehicle operators in the  
9 area, and provides real-time monitoring of an intersection  
10 phase. The real-time monitoring of intersections is indicated  
11 by LEDs on a transponder in the emergency vehicle that show  
12 whether there is a conflict or the intersection being approached  
13 is not preempted. The system also includes the improvement of  
14 an audio alarm to alert pedestrians who may not be aware of an  
15 approaching emergency vehicle for various reasons or are at an  
16 angle where visible signs are not clear.

17 This invention is not to be limited by the embodiment shown  
18 in the drawings and described in the description which is given  
19 by way of example and not of limitation, but only in accordance  
20 with the scope of the appended claims.  
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